



Effects of Polyethylene Ground Plastic Waste Aggregate for Concrete Mixing Proportion

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Research Article

Abstract

In recent times, the production of polyethylene ground plastics has increased markedly in the Philippines. However, current levels of their usage and disposal generate several environmental problems. Recycling is one of the most important actions that are being made to reduce these impacts. The present study used polyethylene ground plastic wastes to investigate their possible use as plastic aggregate in concrete application. The shredded plastic wastes were used in concrete with partial replacement of $\frac{1}{2}$ kg and 1kg by volume of conventional coarse aggregate. Three types of concrete specimens including one without plastic aggregate were used in the study for comparison. All the concrete specimens were tested for their different mechanical properties after a curing period of 28 days. Various physical properties of all aggregates and fresh concrete properties were also tested in the laboratory, these include pound per square inch (psi), Mega Pascal (MPa), Kilo Newton (KN), and the type of fracture. The test for psi, MPa, and kN resulted that concrete mixtures with 1kg ground plastic produced the best result among the three samples having 3150 Psi, 21.7 MPa, and 395.7 KN, respectively. Moreover, the specimens were loaded under a monotonic uniaxial compressive load up to failure by using MATEST hydraulic testing machine with the indicator of kN. The result showed that both standard mixtures of concrete and the standard mixture of concrete with $\frac{1}{2}$ kg polyethylene ground plastic have a comparison infraction that has a result of an SW-Shear Wedge of Type 5, while the standard mixture of concrete with 1kg polyethylene ground plastic has a conical type of a fracture. Based on the several tests conducted, it is concluded that the standard concrete mixture with 1kg polyethylene ground plastic provided the best result compared to other specimens. Furthermore, the use of polyethylene ground plastic waste in the standard concrete mixture provides some advantages like on reduction of plastic wastes, prevention of environmental pollution, and energy saving.

Keywords: Polyethylene ground plastic, aggregate concrete mixture, plastic waste, environmental pollution, plastic recycling, construction

1. Introduction

The plastics industry has developed considerably, and plastics have been already part of our daily lives. Its low density, strength, user-friendly designs, fabrication capabilities, long life, lightweight, and low cost are the factors behind such phenomenal growth. Plastics can be found anywhere, from using it as packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications, water desalination, land/soil conservation, flood prevention, preservation and distribution of food, housing, communication materials, security systems, and other uses (Hossain et al., 2016).

With their large and diverging applications, plastics contribute to the increasing number of wastes in the world. It is a rapidly growing segment of solid waste and the containers and packaging type of plastics had the most tonnage over 14.5 million tons in 2018 (EPA, 2021). This category includes bags, sacks, and wraps; another packaging; polyethylene terephthalate (PET) bottles and jars; high-density polyethylene (HDPE) natural bottles; and other containers. Manufacturers also use plastic in durable goods, such as appliances, furniture, casings of lead-acid batteries, and other products. Plastics are found in nondurable products, such as disposable diapers, trash bags, cups, utensils, medical devices, and household items such as shower curtains. The plastic food service items are generally made of clear or foamed polystyrene, white trash bags are made of high-density polyethylene (HDPE) or low-density polyethylene (LDPE).

Since the late 20th century, everyone has depended on plastic as an affordable, versatile, and durable material. However, since most plastic materials take centuries to degrade, all the plastic that has been sent to landfills and still exists, and yet we're still producing and consuming more of it (cleanstreets.westminster.gov.uk, 2021). These plastics were dumped carelessly on land or in rivers especially in developing countries, before ending up in the ocean, where it threatens marine life.

In the Philippines, a staggering 2.7 million tons of plastic waste are generated each year, 20 percent of which is estimated to end up in the ocean (McKinsey, 2015). Like many rapidly urbanizing countries, the Philippines struggles with unsustainable plastic production and consumption and a waste management infrastructure that relies heavily on open dumping sites, giving plastics an easy path into waterways (Jambeck et al., 2015).

As addressing the country's plastic problem becomes an increasingly pressing priority, more work is needed to establish and enforce legislation, enhance infrastructure, and encourage sustainable production and consumption. Recycling is one of the important actions that are being made to address the issue. However, the Philippine economy is losing up to \$890 million a year due to what is described as a "market failure" in plastic waste recycling efforts, a new World Bank Group (WB) country study showed (Yang, 2021). The total material value which could be unlocked from plastics recycling amounted to \$1.1 billion if four of the country's key plastics resins had 100% collected-for-recycling (CFR) rates and were sold for maximum value in the market. The key plastics resins in the Philippines are Polyethylene plastics that accounted for up to 93 percent of all plastic resins used in the country in 2015 (Yang, 2021).

The present study attempted to utilize the Polyethylene plastic waste aggregate as additives to concrete mixing proportion which makes fewer carbon dioxide emissions and has the potential to pull plastic waste out of the landfill and into buildings, where it could help to make them stronger. Various studies have been conducted to investigate the use of recycled polyethylene plastics as aggregate for concrete mixing such as Jnr et al., (2018), De Jesus et al. (2018), Hossain et al., (2016), Azhdarpour et al., (2016), Islam et al., (2016), Alfahdawi et al., (2016), Saikia and de Brito, (2014), Ganiron Jr, (2014), and Saikia and De Brito, (2012). However, based on the works of literature, limited study has been conducted in the Philippines on utilizing the polyethylene plastic wastes as aggregate to the concrete mixture.

2. Objectives of the Study

The present work aimed to utilize polyethylene ground plastic wastes (PGPW) as an aggregate for concrete mixing proportion. This study also aimed to determine the performance of the concrete mixture added with the various proportion of PGPW in terms of the Pound per Square Inch (psi), Mega Pascal (MPa), Kilo Newton (kN), and the Fracture.

3. Materials and Methods

3.1 Materials

The tools and the equipment of this research were gathered and collected on September 04, 2020, to perform the proper way of mixing plastic in concrete proportion in research experimentation. The shovel is used for mixing sand, cement, gravel, and plastic, the trowel is used for mixing the small number of concrete mixtures, the hammer, push-pull rule, tri square, and pencil. Aiming to successfully mix the said concrete mixing proportion with plastics. The materials of this research were cement, sand, gravel, and plastic use for making cylindrical concrete mixtures. The plain sheet is used in making cylindrical moldings.

3.2 Procedure

The coarse sand and cement were added together in the manual mixing board, after, the gravel was added and then gradually added by water. After mixing, the mixtures are then divided for standard mixing proportion and concrete mixtures with polyethylene ground plastic. The polyethylene ground plastic is then added into the second and third mixtures with the ratio of ½kg and 1kg. Continued mixing should be performed until a homogenous blend is formed. After, moldings are cleaned before casting, and they were placed into the level area. Then, the concrete mix is then poured into the moldings and the concrete surface is leveled using the trowel. After the casting process, moldings are put on the level ground ensuring no vibration and compaction. Subsequently, the molds are kept in a safe place for 24 hours. After a day of the casting process, the molds are removed, and concrete specimens are put into the curing tank for periods of 28 days.

3.3 Strength Tests

Test for hardening of concrete. The fifth and final process is to test the concrete hardness after strengthening, and that is done after drying the samples for 28 days.

Compressive Strength Test. It is the most common of all tests on hardened concrete; in addition, compressive strength is the most important parameter in structural design. Three standard cylindrical forms of six inches diameter and twelve inches height are formed for each mix. The compressive strength test is carried out for 28 days.

Table 1: Concrete mix design for high durability using an additive of ground polyethylene plastic and Portland cement.

Experiment No.	Portland Cement (kilo)	Coarse Sand (cylinder)	Coarse Aggregates (cylinder)	Polyethylene Ground Plastics (kilo)	Water (liter)
1. Standard Concrete Mixtures	6 kg	2 cylindrical	3 cylindrical	0	2 liters
2. Standard Concrete Mixtures with plastic	6 kg	2 cylindrical	3 cylindrical	½ kl	2 liters
3. Standard Concrete Mixtures with plastic	6 kg	2 cylindrical	3 cylindrical	1kl.	2 liters

Portland cement, coarse sand, coarse aggregates, and ground polyethylene plastic mixed with water to get a homogenous mixture then place it on the cylinder mold. The samples are identified by marking the date and named through engraving on the top of the concrete. Samples are left in the cylinder mold until it dried. After 24 hours, removed the cylinder molding and submerged it into the curing tub with a filling of water for 28 days to solidified and cured.

Table 2: Days Curing and Minimum Strength (Psi)

Days	Strength	3000 (PSI)	2500 (PSI)
1	18.0 %	540	450
2	38.0 %	1140	950
3	49.0 %	1470	1225
4	57.0 %	1710	1425
5	63.0 %	1890	1575
6	68.0 %	2040	1700
7	71.0 %	2130	1775
8	74.0 %	2220	1850
9	77.0 %	2310	1925
10	79.0 %	2370	1975
11	81.0 %	2430	2025
12	83.0 %	2490	2075
13	85.0 %	2550	2125
14	87.0 %	2610	2175
15	88.0 %	2640	2200
16	88.5 %	2655	2213
17	90.0 %	2700	2250
18	91.5 %	2745	2288
19	93.0 %	2790	2325
20	94.0 %	2820	2350
21	95.0 %	2850	2375
22	96.0 %	2880	2400
23	97.0 %	2910	2425
24	97.5 %	2925	2438
25	98.0 %	2940	2450
26	99.0 %	2970	2475
27	99.5 %	2985	2488
28	100.0 %	3000	2500

The researchers used the table for the compressive test to check if the experimental sample concrete mixture passes the standard minimum strength for concrete mixtures following the days of curing. For the information, this table was given to the researcher by Quantum Materials Testing and Inspection Laboratory Corporation located at Barangay 79, Marasbaras Tacloban City, Leyte (DPWH-BRS Accredited Laboratory).

Table 3: Minimum Compressive Strength Requirement

Strength Requirement	
Type of location of concrete Construction	Specified Compressive Strength, (PSI)
Concrete Fill	Below 2000
Basement and Foundation walls and slabs walk, patios, steps, and stairs.	2500 – 3500
Driveways, garage, and industrial floor slabs	3000 – 4000
Reinforced concrete beams, slab, column walls	3000 – 7000
Freecast and prestressed concrete	4000 – 7000
High-rise Building (column)	10000 - 15000

Note that the International Building Code (IBC) (Section 1905.1.1) and ACI American Concrete Institute 318 (Section 5.1.1) indicate a minimum specified compressive strength of 2500 psi structural concrete. Simply stated, no structural concrete can be specified with a strength less than 2500 psi. minimum compressive strength requirement for the standard type of concrete construction and its specified compressive strength PSI.

4. Results and Discussions

4.1 Pound Per Square Inch (psi)

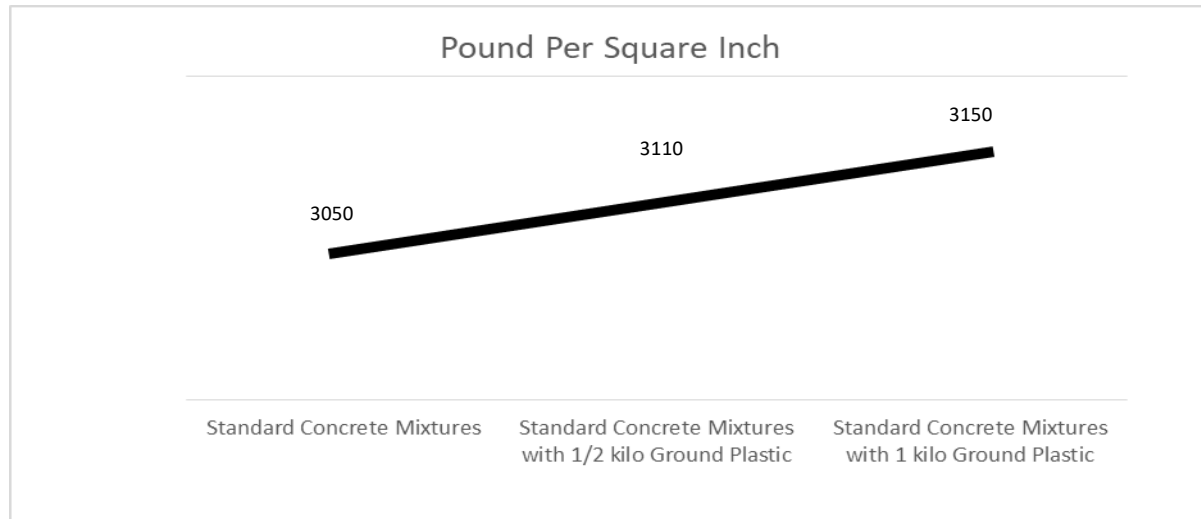


Figure 1: Pound per Square Inch

Figure 1 shows that all mixtures passed the comprehensive strength test and as the result, the concrete mixtures with polyethylene ground plastic are more durable compared to the standard concrete mixture. The standard concrete mixture got a 3050 psi, while the concrete mixture with ½ kg of polyethylene plastic has 3110 psi, and the concrete mixture with 1kg of polyethylene plastic has 3150 psi. Among the three specimens, a concrete mixture with 1kg of polyethylene plastics produced the best result for the psi test.

4.2 Compressive Strength Measure using Mega Pascal (MPa)

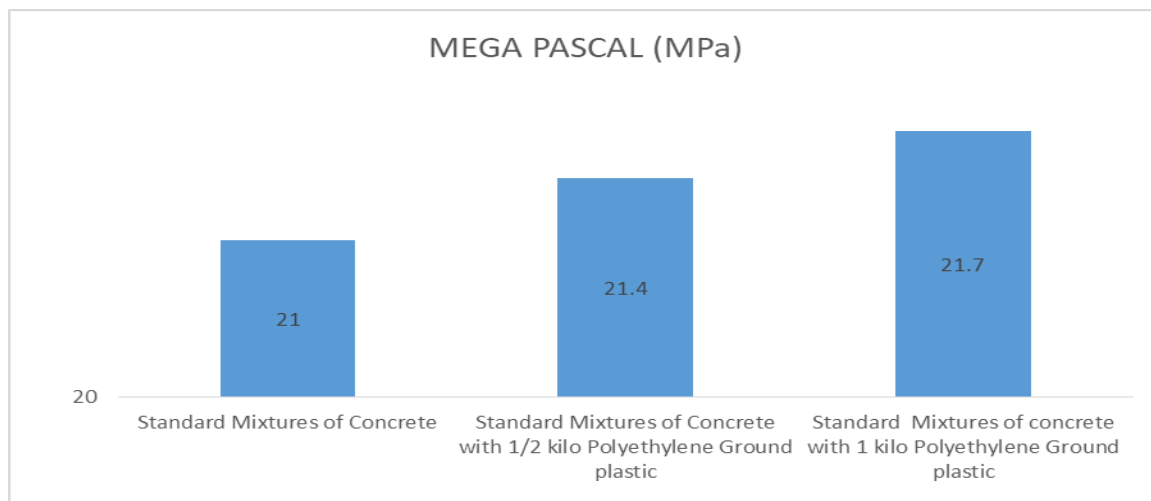


Figure 2: Mega Pascal Test (MPa)

As indicated in Figure 2, we observed that the number of polyethylene plastics behaved differently on concrete strength. Although all the specimens have equal size, they produced a different response. In this case, we found out that the concrete mixture with 1kg of polyethylene plastics produced the highest MPa of 21.7 compared to other specimens, with 21 MPa for the standard concrete mixture, and 21.4 MPa for the concrete mixture with $\frac{1}{2}$ kg polyethylene plastic.

4.3 Kilo Newton (kN)

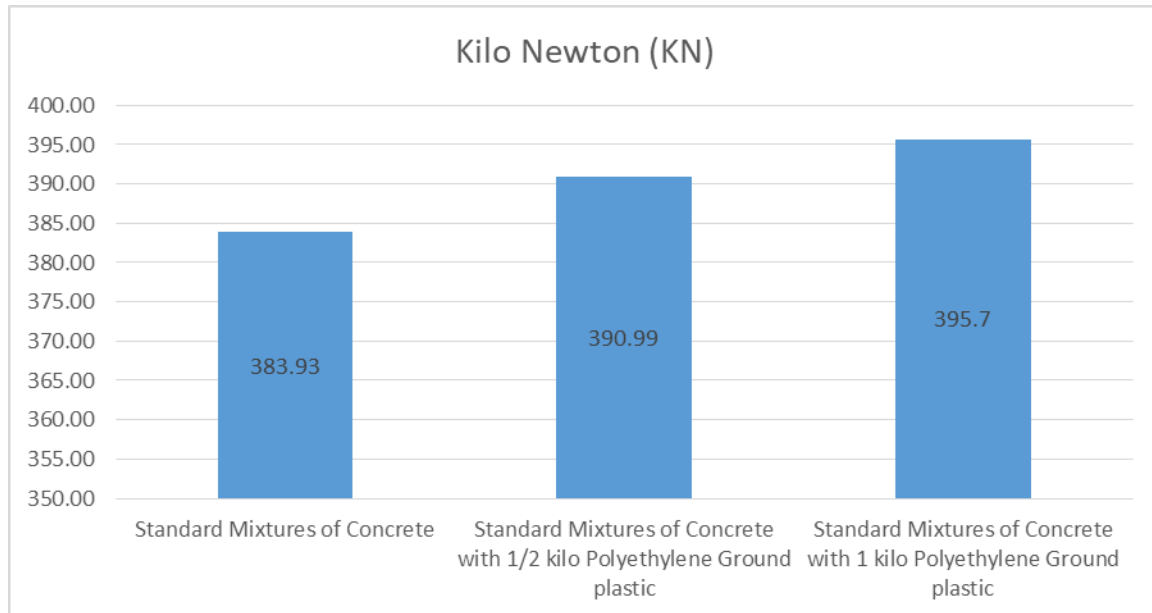


Figure 3: Comparison of Strengths of the 3 specimens in kN

Figure 3 illustrates the comparison of the strength of the 3 specimens in Kilo Newton. The specimens are the conventional concrete mixtures, concrete mixtures with $\frac{1}{2}$ kg polyethylene ground plastic, and concrete mixtures with 1 kg additive. As indicated, concrete mixtures with 1 kg produced the highest score for the compressive strength test in kN.

4.4 Fracture

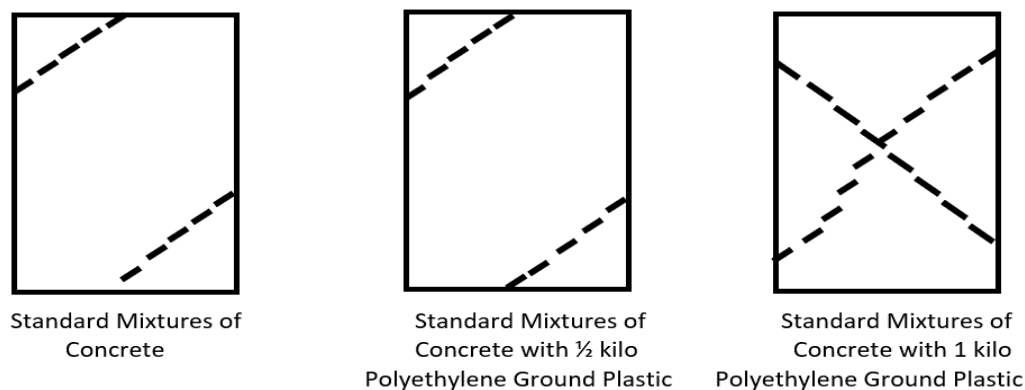


Figure 4: Fracture Tests

The specimens were loaded under a monotonic uniaxial compressive load up to failure by using MATEST hydraulic testing machine with the indicator of KN. Before testing, the faces of the specimens were placed with a surfacing machine, to ensure parallelism and flatness of the faces of support. In this experiment, both standard mixtures of concrete and standard mixture of concrete with ½ kg polyethylene ground plastic have a comparison infraction that has a result of an SW-Shear Wedge of Type 5. It is a side fracture at the top or bottom or both top and bottom, that occurs commonly with unbonded caps. The Standard mixtures of concrete with 1 kg polyethylene ground plastic is a conical type of fracture. It is reasonably well-formed cones on both ends, less than 1 in. (25 mm) of cracking through caps.

5. Discussions and Conclusion

Several studies have assessed the effect of polyethylene ground plastic waste aggregate on the behavior for concrete mixing proportions. According to Rahim et al., (2013), polyethylene plastic wastes are best utilized in cement, sand, aggregate, concrete, and other construction materials. It also helps in reducing the cost of concrete manufacturing (Rahim et al., 2013), and helps increase the strength, hardness, and resistance of concrete materials (Tamrin & Nurdiana, 2021) thus, increasing construction safety (Treceñe, 2019).

The concrete workability indicates the consistency of the concrete mix during the process. The use of plastics as additives to the concrete mixture has affected the compaction caused by the contact with the surface and the internal friction (Tamrin & Nurdiana, 2021). Further, considering that plastics are lightweight and resistant to weather, therefore, plastics are good additives materials for concrete. Previous studies indicated that added materials, including plastics, can improve the properties of concrete given appropriate percent (Poonyakan et al., 2018; Bahij et al., 2020).

In the present study, based on the several tests conducted, it is concluded that the standard concrete mixture with 1kg polyethylene ground plastic provided the best result compared to other specimens. This study has contributed to the understanding that the use of polyethylene ground plastic waste in the standard concrete mixture provides some advantages like on reduction of plastic wastes, prevention of environmental pollution, and energy saving. As part of the continued growth of the Philippines (Treceñe, 2021), this will help the country in the fight against plastic wastes.

Author Contributions: Sofio Rocky conceived the idea and facilitate the methods that will be used in the study, while Marc Charlie T. Regis, Joeffrey A. Catalon & Jilson V. Solayao did the experimental process, gathered the data, and analyzed, and wrote the paper. Ramelito R. Paler made some revisions and polished the whole paper for publication.

Conflict of interest: The authors declare no conflict of interest.

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